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Presidential Address

by

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Presidential Address.

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(Read May Meeting 1915)

Micheli and The Discovery of Reproduction in Fungi.

(With Four Plates)

I have long been of the opinion that no man can have a full conception of any subject upon which he may specialize until he has studied the history of its development. Imbued with this belief, I have spent a considerable amount of time, during the past six years, in two of the most famous of the Old World libraries, perusing many ancient and modern works written by my predecessors upon those peculiar plants which are known as fungi. In the course of my reading, I have come upon a work published some two centuries ago by an Italian, Pier' Antonio Micheli, in the pages of which a new and a very bright light was thrown on fungi, the fact for the first time being made clear that fungi possess reproductive bodies which are able to bring about the propagation of the species. This important discovery made it possible for later botanists to work out the life-histories of fungi, with a consequent enrichment of the science of Botany in general, and a great advance in Plant Pathology in particular.

The discoveries of Micheli in connection with the reproduction of Fungi seem to me to be so interesting in themselves and of such historic importance, that I intend in this Address to lay them before you. Since the crucial experiments devised by Micheli were carried out in the year 1718, my remarks will perhaps serve, although they are a little previous, as a bicentenary celebration.

In order to give to Micheli's work a proper historical background, so that we may see it in its right perspective, we shall first consider the question of reproduction in fungi as it appeared to Micheli's predecessors.

The view generally held before the time of Micheli on the origin of fungi was that these plants arise by spontaneous generation. The physician and poet, Nicander (*circa* 185, B.C.), referred to a fungus as being "an evil ferment of the earth."[1] From the writings of Theophrastus, Plutarch, Martial, Pliny, and others, it is made evident that the old Greeks and Romans held the view that Truffles are produced through the action of lightning during thunder-storms.[2] Plutarch actually has a long discourse in his *Table Talk* entitled "Why Truffles are thought to be produced by Thunder" in which it is proved to the satisfaction of the talkers that Truffles owe their existence to lightning which, being mixed with heat, pierces into the earth and so alters it as to form the fungi subterraneously. The delightful argument is put forward that since, during thunder-storms, flame comes from moist vapours and deafening noises from soft clouds, there need be no surprise that, when lightning strikes the ground, Truffles should spring into existence.[3]

Phanias who was quoted by Athenæus in the Third Century, A.D., said that Fungi and Truffles are like Ferns in that "they produce neither bloom nor any trace of generation by buds or seeds."[4] That the Greeks and Romans took notice of the lamellæ of the Agaricineæ is shown by the fact that they mistook certain simple corals which have radiating calcareous plates, for fungi turned to stone;[5] but there is nothing in the classical writings to suggest that the ancients ever observed the spore-dust which the lamellæ give forth.

The Revival of Learning in the Sixteenth Century brought new life to the science of Botany. A large number of botanical works known as Herbals were printed. The first ones were simply commentaries on Dioscorides, a Greek physician, who lived in the time of Nero and Vespasian and who had described about five hundred kinds of plants in his *Materia Medica*. The Herbalists had a great respect for classical authority. One of the consequences of this was that they accepted the views of the ancients in respect to the nature and origin of fungi. Thus, in 1552 Bock,[6] in his Herbal of the plants of Germany, said: "Fungi and Truffles are neither herbs, nor roots, nor flowers, nor seeds, but merely the superfluous moisture of earth, of trees, of rotten wood, and of other rotting things. This is plain from the fact that all

[1] Nicander, Alexipharmaca, 521-536.

[2] *Cf.* A. H. R. Buller, The Fungus Lore of the Greeks and Romans, Trans. Brit. Mycological Soc., 1915.

[3] Plutarch, Symposiaca, Book IV, Question 2.

[4] Phanias, *apud* Athenaeus, Deipnosoph., II, 56-59.

[5] Theophrastus, *apud* Athenaeus, *loc. cit.*, II, 61, f.

[6] Bock (Hieronymus Tragus), De Stirpium maxime earum quae in Germania nostra nascuntur usitatis, etc., Argent., 1552, p. 942.

fungi and truffles, especially those which are used for eating, grow most commonly in thundery and wet weather, as the poet of Aquinum says: *Et facient lautas optata tonitrua coenas.*"[1] Matthiolus, in the Prague edition of his Herbal, dated 1563, expressed the same views in almost identically the same words.[2]

The doctrine of spontaneous generation for fungi was accepted by Cesalpino, the chief exponent of Aristotelian botany in the sixteenth century, he who discussed the seat of the soul in plants and argued that it exists in the pith where the stem and root are united. In his great work, *De Plantis Libri XVI*, published in 1583, he says concerning Fungi and certain other organisms: "Some plants have no seed; these are the most imperfect, and spring from decaying substances; they therefore only have to feed themselves and grow, and are unable to produce their like; they are a sort of intermediate existences between plants and inanimate nature. In this respect Fungi resemble Zoophytes which are intermediate between plants and animals, and of the same nature are the Lemnæ, Lichens, and many plants which grow in the sea."[3]

Toward the end of the Sixteenth Century, a reaction against the views of the ancients concerning the origin of fungi set in. A Neapolitan by the name of Porta, in the year 1591, published a book called *Phytognomonica* in which he had a chapter headed: *Contrary to the Ancients All Plants are Provided with Seed.* In this chapter, he refers to fungi and says: "From fungi I have succeeded in collecting seed, very small and black, lying hidden in oblong chambers or furrows extending from the stalk to the circumference, and chiefly from those which grow on stones, where, when falling, the seed is sown and sprouts with perennial fertility. Falsely therefore has Porphyrius said that fungi, since they do not arise from seed, are the children of the gods. So also in Truffles, a black seed lies hidden. On this account, they come forth in woods where they have frequently been produced and have rotted away. And I have often seen them arising where the washings of tan or the tan itself is thrown away."[4] Porta had undoubtedly guessed aright. It is evident that he did actually set his eyes upon the reproductive bodies of fungi. The black dust, which he mentions as lying hidden in oblong chambers or furrows extending from the stalk to the circumference, was probably the dark spores which

[1] The poet of Aquinum was Juvenal. The line cited is from Juvenal's Sat. V, in which a feast is described: "After this Truffles will be handed round, if it is Spring, *and if the longed-for thunders have produced the precious dainties.*"

[2] Matthiolus, Neu Kreüterbuch, Prag, 1563, p. 476.

[3] Andrea Cesalpino, De Plantis Libri XVI, Florence, 1583, lib. I, cap. XIV, p. 28.

[4] J. B. Porta, Phytognomonica, 1591, Francofurti, lib. VI, cap. II, p. 369.

are produced as minute particles on the hymenium which lines the interlamellar spaces of such Agarics as Panæolus and Coprinus. His Truffles may possibly have included Scleroderma which produces its spores within its cleistocarps as a black powder, whilst the fungi which he observed on tan were probably Mycetozoa such as the well-known Flowers of Tan, *Fuligo varians*, which develops its spores in the form of a dark powder surrounded by a thin and fragile covering. We must therefore acknowledge that Porta rightly recognised the spore-dust of certain fungi, as consisting of reproductive particles corresponding in function to the seeds of Higher Plants; but he had no proof to offer. He performed no cultural experiments and therefore his view could not be at all convincing to sceptics.

The seventeenth century saw the invention and improvement of the microscope, an instrument fraught with enormous possibilities for the increase of knowledge. With the employment of this new aid to research, the hitherto invisible spores of certain fungi were revealed to the curious eyes of Hooke and Malpighi; but the final discovery and correct interpretation of the reproductive bodies was left, as we shall see, to Micheli.

Robert Hooke issued his *Micrographia or some Physiological Descriptions of Minute Bodies made by Magnifying Glasses with Observations and Inquiries therefrom* in 1665. In his pioneer work in the world of the minute, he brought under his microscope a great variety of objects among which were certain fungi. He gave descriptions and illustrations of a White Mould (Mucor) which he found growing on the sheepskin cover of a book, and also of "a plant growing in the blighted or yellow specks of Damask-rose-leaves, Bramble-leaves and some other kinds of leaves."[1] He failed to discover the spores in the sporangia of the Mucor, but in the case of the second fungus which it is evident from his illustration was a Phragmidium, one of the Rust fungi, he certainly observed the teleutospores.[2] His illustration is the very first ever made of the reproductive bodies of a fungus: it shows several Phragmidium pustules with the stalked spores protruding outwards, but the multicellular nature of the latter was overlooked. Although it is quite certain that Hooke saw these spores, he failed to interpret them correctly: judging them by their external form he took them for seed-pods, and thought that they might contain seed which would be liberated like that from the follicles of the Columbine.

Hooke, notwithstanding his microscopic work, thoroughly believed in spontaneous generation. Even in the case of his Phragmidium, he supposed that the fungus arose in the first place by putrifaction

[1] Robert Hooke, Micrographia, 1665, pp. 121-127.
[2] *Ibid.*, Fig. 2, Schema XII.

of the leaves. However, he also thought that when it had so arisen, it might produce seeds which would propagate the fungus from leaf to leaf. He regarded highly organized plants as compound, and imagined that during their decay, they break up into simpler ones. He thus accounted for the coming into existence of the Mistletoe on the Oak, the Jew's-ear Fungus on the Elder, and Lichens on the trunks of trees. "And this," he says, "we see to be very much the method of nature throughout its operations, *putrefactive Vegetables* very often producing a Vegetable of a much less compounded nature, and of a much inferior tribe."[1]

So far as Mushrooms are concerned, Hooke concluded from his observations that they are generated without seed in any part of them, "for," he says, "having considered several kinds of them, I could never find anything in them that I could with any probability guess to be the seed of it, so that it does not as yet appear (that I know of) that Mushrooms may be generated from a seed, but they rather seem to depend merely upon a convenient constitution of the matter out of which they are made, and a concurrence of either natural or artificial heat."[2] He also concluded that Moulds "may be produced at any time from any kind of putrifying Animal or Vegetable Substance, as Flesh, etc., kept moist and warm . . ." and that "they require no seminal property."[3]

Malpighi, one of the founders of vegetable histology, published his *Anatome Plantarum* under the auspices of the Royal Society of London in 1675-1679. In this work, several pages are given to fungi, which are dealt with along with Mistletoe, Lichens, Lunularia, and Mosses, under the heading *De plantis quae in aliis vegetant.*[4] The anatomy of the fungi which were investigated, is illustrated in a Plate, (Tab. XXVII) which contains twenty-three sketches of various Moulds (his Mucedo) and three of an Agaric (his Fungus). The Moulds were found on the putrescent pericarps of melons, lemons, and oranges, upon wood, and upon bread. Judging by the illustrations, the species which Malpighi observed, included a Pin Mould (*Rhizopus nigricans*)[5] a Monilia,[6] a Botrytis,[7] and a Penicillium.[8] Malpighi actually saw the spores of some of these fungi, for in several sketches he shows the spores properly attached to sterigmata which come off from a common

[1] *Ibid.*, p. 123.
[2] *Ibid.*, p. 127.
[3] *Ibid.*
[4] M. Malpighi, Anatome Plantarum, Londini, 1679, pars altera, pp. 62-67.
[5] *Ibid.*, Tab. XXVII, Fig. 108, F.
[6] *Ibid.*, Fig. 108, L.
[7] *Ibid.*, Fig. 108, C, D, K, etc.
[8] *Ibid.*, Fig. 109, V, T.

sporophore.[1] The Monilia is represented as consisting of chains of oidia. There is one drawing of a branched mycelium like that of Penicillium,[2] and another showing mycelium, sporophores, and spores, all in connection with one another.[3] The apperception of microscopic plants by the early observers was naturally influenced by a phanerogamic bias, and Malpighi, like his predecessor Hooke, failed to interpret the spores correctly: he regarded the sporangiophore with the spores as an inflorescence, and the spores themselves as florets. Malpighi also gave an account of the development of a small Agaric (his Fungus) growing on wood. From its shape and from the hairs, each crowned with a drop of fluid, the species may have been *Psathyrella disseminata* or one of the smaller Coprini. A network of hyphæ on the surface of the wood was observed and from it the fruit-body was seen to spring, but no mention is made of seeds in the text, so that it is evident that Malpighi failed to discover reproductive bodies in fungi of the Mushroom type.

In summing up the chapter to which reference has just been made, Malpighi says that it is evident that the Mistletoe is propagated by seeds and, as for the rest of the plants which grow on others, "up to the present we do not know how they are multiplied and born; especially among these are the Fungi and Mucedo. Various are the substances on which Fungi may arise; and as I have been able to see, for the most part they spring up either on wood or on pieces of it; and at their beginning there grows luxuriantly a large network of filaments from which, when they are at length united into a bundle, a stalk is produced. Wherefore either Fungi, Mucedo, and Moss have their own seed, by which their species is propagated, or they sprout from the growth of fragments of themselves as happens in other plants."[4] It is also suggested that the seeds or pieces may be blown about by the wind and thus spread from place to place. Malpighi, therefore, unlike Hooke, was not disposed to believe in the spontaneous generation of fungi but favoured the more rational seed theory.

The investigations of Hooke and Malpighi were soon followed up by Leeuwenhoek.[5] This Dutch naturalist who, like Hooke, examined a great variety of minute objects, was the first observer not only of the Hydra and Rotifers but also of the red corpuscles of the human blood,

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[1] *Ibid.*, Fig. 108, D, L, M, N, R, S.

[2] *Ibid.*, Fig. 109, T, V.

[3] *Ibid.*, Fig. 108, R, S.

[4] *Ibid.*, p. 67.

[5] Anton van Leeuwenhoek (1632-1723). For his life and work *vide* Miall, The Early Naturalists, their Lives and Work, London, 1912, pp. 200-223. Leeuwenhoek's works, translated by Samuel Hoole into English from the Dutch and Latin editions, were published in London in 1789.

of Yeast cells,[1] Volvox, Haematococcus, Polytoma, and other unicellular forms of life. He also gave the first description of spermatozoa which had been demonstrated to him by a physician named Hamm. In 1683, in a letter to the Royal Society, he announced the discovery of Bacteria which he had found when examining the white fur taken from his own teeth.[2] His microscopes were simply double-convex lenses which gave various degrees of magnification. The high powers, owing to loss of light, could only be successfully employed when the object was transparent and directly illuminated by the sun. Medium powers gave the best results. Since microscopes had become good enough to detect even the smallest kinds of living organisms, it was not the fault of instruments that the spores of Hymenomycetes, such as the Mushroom, and of fungi generally, remained unknown at this time.

Tournefort, in 1707, in his admirable account of the culture of Mushrooms in artificial beds, definitely ascribed the origin of these fungi to seeds. It is true that he failed to understand the function of the lamellæ which he called the leaves of the fungus, and was also compelled to confess that Mushrooms "possess neither flowers nor observable seeds"; but several times he intimated his belief in microscopic reproductive bodies. In one place, after describing the mycelium which he pointed out gives rise to young Mushrooms, he says: "According to appearances these white threads are nothing but developed seeds or germs of Mushrooms and all these germs may be enclosed in so small a space that one can only perceive them, however much care one may take, after they have grown out into little hairs."

Another Frenchman whose name is not recorded, showed in a report to the French Academy upon Tournefort's memoir on Mushrooms, that he had perfectly correct ideas about the invisible reproductive bodies of fungi, although, like Tournefort, he evidently considered that they had not yet been observed.[4] His scientific imagination which had been excited by the discovery with the microscope of the spores of Ferns a few years before, enabled him to see the vast hosts of fungus spores which we now know are scattered in the most wonderful profusion everywhere in

[1] Leeuwenhoek, Arcana Naturae detecta (1680), Vol. II, pp. 1-14. He discovered that the Yeast cells give off bubbles of gas in fermenting wort. Cited from Miall pp. 219-220.

[2] Leeuwenhoek, Phil. Trans. Roy. Soc., No. 159 (1684); also Arcana Naturae detecta (1683). Cited from Miall, p. 220. *Cf.* Hoole's Translation, p. 118.

[3] Tournefort, Observations sur la naissance et sur la culture des Champignons, Mém. Acad. Sci. de Paris, 1707, p. 61.

[4] An anonymous Frenchman, Sur les Champignons, Histoire de l'Acad. Roy des Sci., 1707, pp. 46-49. The writers of the Histoire all wrote anonymously.

nature. Assuming that fungi possess microscopic seeds, he gave a rational explanation of the origin of fungi in horse-dung, etc. He supported his views by analogies with seed-plants, and estimated the value of the minute size of the reproductive bodies. His belief that all fungi are reproduced from seed is expressed as follows: "We should be still less to be excused than the ancients, if we thought as they did, because for us the number of plants which have no visible seed is very much smaller. Therefore without fear, we can advance the view that all fungi have seeds, and we may rest assured that, if ever experiment should succeed in clearing up the matter, it will justify us."

The writings of Tournefort and of the anonymous Frenchman which have just been cited, show that, at the beginning of the eighteenth century, the existence of reproductive bodies was a matter rather of speculation than of exact knowledge. Nevertheless, the art of raising Mushrooms on artificial beds was at this time well known and extensively practised, more especially by the gardeners around Paris. A flood of light is thrown on the Mushroom culture of the period in the very interesting paper of Tournefort, to which a reference has already been made, called *Observations sur la naissance et sur la culture des Champignons*.[1] The technique of preparing the dung, turning it with a fork, and moistening it with water, preparing spawn, drying it for keeping, and sowing the beds with it, covering the beds with earth and regulating their temperature, had been developed; so that it is evident that gardeners, by the beginning of the eighteenth century, had already had a great deal of experience in growing Mushrooms.[2] Even such terms as *gobeter*, *lardon*, etc., which are still used by Parisian champignonists, were commonly employed. The beds were made in the open and not in caves as at present.[3] To procure spawn in the first place, manure beds were made up at the beginning of April, and it was left to chance to develop the mycelium of the Mushroom. At the be-

[1] Tournefort, *loc. cit.*

[2] The exact date when Mushrooms began to be cultivated from spawn is uncertain. In England the practice appears to have been unknown up to the middle of the seventeenth century, for writers like Francis Bacon (Sylva Sylvarum, London, 1627, pp. 140-141) and Parkinson (Theatrum Botanicum, London, 1640, pp. 1316-1324) make no mention of it; but in 1731 Miller (Gardener's Dictionary, London, art. Mushrooms) gives full details for the making of Mushroom beds, and says that Mushrooms "are annually cultivated by the Gardeners near London. . . . who cultivate them for sale."

[3] Caves were not used at Paris for Mushroom culture until the latter part of the nineteenth century. Their employment was initiated by M. Monin who died in 1905. *Cf.* Cohendy, La Culture des Champignons comestibles (Journal Mensuel), Paris, Ann. 2, 1908, p. 271.

ginning of August, the desired result was frequently obtained: the dung was found to be turning white. Masses of the infected manure about the size of one's fist were then used to spawn other beds from which Mushrooms were to be raised. It was only by using spawn or *lardons* thus specially prepared that the beds could be made financially successful. Before the discovery of the *lardon* method, attempts at Mushroom culture were too full of risks to be generally made. We do not know the name of the man who, at some time previously to the year 1700, discovered and taught the art of using spawn. He remains unknown to fame. Perhaps he was a Parisian *jardinier* with a little more originality than his fellows; but whoever he was, to him belongs a large part of the credit for making possible the modern industry of raising Mushrooms which is now extensively practised in caves and special Mushroom houses, and which gives employment to several thousands of workers.[1] At the present day, at Paris, to obtain vigorous spawn is still one of the greatest difficulties of Mushroom culture. Special searchers hunt over old manure piles in the country, and thus often come across virgin spawn. This they bring to the city in baskets and sell at a good price to the Mushroom growers who increase it in amount by special culture.[2] Also, virgin spawn is now raised from spores in pure cultures by a Company in Paris and sold in cartridge-like masses or *cartouches*;[3] whilst, in the United States of America, pure spawn has been prepared by propagating the interior hyphae of young stipes.[4] The shape of the beds two centuries ago, as shown by Tournefort's illustrations, was almost the same as that which one may now see anywhere in the caves near Paris. Experience has shown that this shape cannot be much altered without a sacrifice in economy.[5] Tournefort's Plate not only contains the first illustration of artificial Mushroom beds, but also the first representation of mycelial strands showing the mode in which they swell out to form young Mushrooms.

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[1] Fifteen hundred workers are employed in raising Mushrooms for the markets of Paris alone. The value of the Parisian industry is upwards of 6,000,000 francs per annum. Statistics collected by the Syndicat des Champignonnistes de France. *Vide* M. P. M. Biers, La Culture du Champignon de couche, Bull. de la Soc. Mycolog. de France, T. 24, 1908, p. 196.

[2] This fact I have obtained by personal enquiry of the Mushroom growers when visiting the Mushroom caves in the suburbs of Paris in 1912.

[3] I have seen the *cartouches* in use at Paris.

[4] B. M. Duggar, The Principles of Mushroom growing and Mushroom Spawn making, U. S. Dep. of Agric., Bureau of Plant Industry, Bull. No. 85, 1905.

[5] The beds in the caves of Paris are almost triangular in cross-section, the base being 40-60 cm. wide. The beds are placed in rows, side by side. The total length of all the beds together, in the caves of Paris, has been estimated at 1460 kilometres. *Vide* Biers, *loc. cit.*

The view expressed by Tournefort in 1707 that all fungi spring from seed was by no means generally accepted at that time, for shortly afterwards, in 1714, Marsigli[1] and Lancisi[2] expressed the opinion that fungi on tree-trunks are merely the diseased parts of the trees resulting from a derangement of the fibres, and that ground-fungi are the product of the oily sap left by decaying vegetation. In 1738, Jussieu joined in the controversy and opposed himself to Marsigli and Lancisi. Jussieu held that tree-fungi are independent plants quite different from the trees on which they grow, and are produced from seeds. Unlike previous writers, with the exception of Porta whose observations on the reproductive bodies of fungi in 1591 had long been forgotten, he pointed out exactly where the seeds are to be found in several different kinds of fleshy fungi. He says: "But this supposition of seeds is by no means imaginary; for they make themselves felt to the touch in Mushrooms, where the cap has leaves underneath, like meal, especially when they begin to decay; one perceives them easily with the help of a lens in those whose leaves are black at the margin; one finds them in the form of a dust in those that are called *lycoperdon;* they appear in fairly large grains on the Champignon de Malte, they are placed in chambers made to contain them in hypoxylon." He then describes the *Fungus minor allii odore* and mentions the powder on the gills.[3] These observations leave no doubt that Jussieu did actually observe spores on the gills of certain of the Agaricineæ, in Puffballs, and in the sporocarps of one of the Ascomycetes. However, Jussieu did not bring forward any experimental proof that the spores have a reproductive function.

We now come to the Florentine botanist Micheli whose discoveries in connection with the reproduction of fungi mark an epoch in mycology. This gifted observer was born in 1679. His parents were poor and took but little care with his education. It is said that they intended to make him a bookseller. However, his strong desire for natural knowledge was not to be denied. He devoted himself to Botany, taught himself Latin in which language botanical books were then written, and gradually gained a wide and intimate acquaintance with plants. The Court recognised his ability by making him botanist to Cosmo III, the Grand Duke of Tuscany, with the care of the public

[1] Marsiglius, Dissertatio de generatione Fungorum, Romae, 1714.

[2] Lancisus, De ortu et textura Fungorum, Romae, 1714.

[3] Antoine de Jussieu, De la necessité d'établir dans la methode nouvelle des plantes, une classe particulière pour les Fungus, à laquelle doivent se reporter non-seulement les champignons, les agarics, mais encore les Lichen, Mém. de l'Acad. Roy. des Sci., 1728, pp. 377-382. The *Fungus minor allii odore* was probably either *Marasmius alliaceus*, *M. scorodonius*, or *M. porreus* all of which smell of garlic.

gardens at Florence. He soon obtained a number of new plants from the more flourishing garden of Pisa, and with the co-operation of his friends, a Botanical Society was founded at Florence in the year 1717. In 1729, when he was fifty years old he published the results of his scientific observations in a great work which was printed in his native city. The cost of the plates which numbered one hundred and eight, was defrayed by a large number of patrons interested in natural history.[1]

Among them were Hans Sloane who was then President of the Royal Society, William Sherard, the Oxford botanist, and several other Englishmen. The work is usually referred to as the *Nova Plantarum Genera*, but translated from the Latin its full title is *New genera of plants, arranged after the method of Tournefort, in which 1900 plants are enumerated, of which almost 1400 have not before been observed, while others are referred to their proper places; about 550 of these which it seemed advisable to illustrate, have been represented on 108 copper plates; with additional notes and observations regarding the planting, origin, and growth of fungi, mucors, and allied plants.* It is a fine quarto volume with excellent plates which, in many copies that have come down to us, look almost as fresh as when they were issued. In order to collect new plants, Micheli was commissioned to travel in Northern Italy. In 1736, he visited the famous Mount Baldus and the Venetian Isles. Unfortunately he was attacked by pleurisy from the consequences of which he never recovered. He returned to Florence where he died in 1737 in the fifty-eighth year of his age. He was buried in the Church of Sante Croce where lie the ashes of some of the greatest men of Italy and of all time,—of Michael Angelo, Galileo, Dante, Machiavelli, and Alfieri. Well may the people of Tuscany be proud of their great forerunners. On the tablet erected to Micheli's memory there is a Latin inscription which translated reads as follows:

"Pier' Antonio Micheli lived 57 years and 22 days, happy although in moderate circumstances, an expert in natural history, a leading botanist of Tuscany, well-known everywhere for his researches and writings, and much beloved by all the worthy men of his age on account of his wisdom, sweetness of disposition, and modesty. He died on the second of January, 1737. His friends gathered contributions and erected this tablet."

Micheli was never married. His contemporaries describe him as a man of the most pleasing, modest, and liberal manners, no less ready to communicate than eager to acquire knowledge. He had good health until his last illness when, as one of his biographers relates, "he placidly

[1] At the beginning of his work Micheli gives a list of 197 patrons.

yielded to his fate, not only with Catholic ceremonies but with the feelings of a Christian."[1]

Micheli's botanical work is specially distinguished by the accurate illustration of several difficult families of plants which his predecessor Tournefort had left untouched. The genus Carex first assumed an intelligible form under his hands. He described a large number of Lichens which had previously been neglected, and he was the first to illustrate the reproductive structures in Mosses although he did not understand their significance. For the Liverworts he founded the genera Blasia, Marsilea, Jungermannia, Sphaerocarpus, Anthoceros, Targionia, etc. He also studied Sea-weeds and had numerous plates engraved which he intended to publish in a second volume of his great work; but he died before this could be accomplished. Like his contemporaries he confounded Corals and Hydrozoa with Sea-weeds, and made a genus out of the present hydroid *Sertularia* which he called *Dillenia* after the botanist Dillenius. He also made a large collection of fossils, but he never published anything concerning them. The chief products of his pen, in addition to the *Nova Plantarum Genera*, were: an account of his botanical tours in Italy, an alphabetical catalogue of all the plants in the garden at Florence, and an octavo pamphlet on Orobanche which he rightly regarded as a noxious weed which ought to be exterminated. He said that the best way to get rid of Orobanche would be to eradicate the beans or other plants to which the parasite attaches itself, in the month of April, for the parasite which is an annual plant, would thus be prevented from producing seeds upon which it is dependent for its continuance from year to year.

Notwithstanding his contributions to other branches of Botany, it is as a mycologist that Micheli has the greatest claim to remembrance by posterity. He described a large number of new species, founded a number of new genera, and arranged them in a new system which he based on his own discoveries. The genera Polyporus, Phallus, Botrytis, Aspergillus, Clathrus, Mucor, Lycogala, and Geaster all owe their names to him. Micheli was a leader in the description of the smaller fungi, particularly of the Moulds and of the Mycetozoa. He also invented the name *Puccinia* which he used to include our Gymnosporangium and Ceratiomyxa. He described several hundred species of fungi like the Mushroom, and therefore found it necessary to elabo-

[1] As a source of facts for Micheli's life and general work as a botanist, I have consulted J. E. Smith's article *Micheli* in Rees' Cyclopaedia, Vol. XXIII, London, 1819; J. E. Smith's A Sketch of a Tour on the Continent, ed. II, London, 1807, vol. I; Dawson Turner's Extracts from the Literary and Scientific Correspondence of Richard Richardson, Yarmouth, 1835; etc.; and Micheli's Nova Plantarum Genera.

rate a new system to contain them; and he set his system out in synoptical form. The only previous attempt at such a classification had been made by Vaillant and was of a very rudimentary kind. But this is not the place to enter on a full discussion of Micheli's systematic work. Our special business just now is to consider his investigations in connection with the reproduction of fungi.

Micheli's investigations upon the reproduction of fungi seem to have been guided by a desire to discover flowers and seeds in these plants so that he might bring Fungi into line with Flowering Plants, and thus make a useful contribution to systematic botany. Armed with a microscope of very simple construction, he set about the task of examining the most varied species of fungi for the expected seeds. Success soon crowned his efforts. So far as the Hymenomycetes are concerned, he found the spores (which he called seeds) on the gills of Agaricus (his Fungus), in the tubes of Boletus (his Suillus), on the spines of Hydnum (his Erinaceus,) and on the outer surface of the branches of Clavaria. In all these cases, he illustrated his remarks with drawings (Pl. I, A, C, F, I, K, etc.; Pl. II, A-F, I-K; Pl. III, F, G); but as, in describing his genus Agaricum which included such dimidiate forms as Fomes, Polyporus, *Tremella mesenterica*, *Hirneola auricula-judae*, Corticium, etc., he speaks generally of seeds as being present, he doubtless saw them in species belonging both to the Tremellineae and the Thelephoreae. Among Gastromycetes, he found spores in Lycoperdon (Pl. III, H), in the foetid liquid on the cap of Phallus, and in the peridiola of the Nidularieae, (Pl. III, I-K). Furthermore, descending in the scale, Micheli showed that his seeds are also present in the asci of certain Discomycetes (Pl. III, L), in the perithecia of Pyrenomycetes (Pl. III, M, N), in Truffles, in Lichens (Pl. III, O, P), in the sporangia of Mucor (Pl. IV, B), upon the sporophores of Aspergillus and Botrytis (Pl. IV, D, E, G), and, finally, in the sporangia of the Mycetozoa (Pl. III, A-E). A considerable amount of evidence was thus accumulated to support the general conclusion that reproductive bodies are present in all fungi.

There is nothing in Micheli's text to indicate to us the exact species of the Agaricineae which he used for his investigations, but it is not improbable that among them was a Panaeolus. He discovered that in some species of lamellate fungi, the spores can be seen on the lamellae in groups of four (Pl. I, I). In such a Panaeolus as *Panaeolus campanulatus*, if one examines a gill in face view with the low power of the microscope, the well separated groups of four black spores can be distinguished very quickly and clearly. In other fungi, Micheli found that the spores appeared not in groups of four but scattered irregularly over the gill surface. Some of these fungi were undoubtedly

Coprini as is evident from the fact that one of them was obtained from a manure heap and possessed the characteristically large cystidia (Pl. III, P-R).[1] Now, as I have shown in a special paper, the basidia of the Coprini are usually dimorphic, about one-half of them being much longer than the other half.[2] With the dimorphism is correlated a crowding of the basidia together. Owing to the crowding, the spores of the long basidia often overlap those of the short basidia. In the Coprini, on this account, it is not so easy with low magnification to distinguish the groups of four spores as it is in Panaeolus and many other non-Coprinus species of Hymenomycetes. Doubtless, it was the crowding of the spores together which led Micheli to believe that in the Coprini the spores are scattered singly over the gill surface. Since Micheli observed the spores of a Hydnum, of a Boletus, and of a Clavaria, it is clear that he did not confine his attentions to dark-spored fungi. However, of all the species which he used, none could have been more favourable for his investigations than the Coprini, for in them the gills are so extremely thin, that light easily passes through their whole thickness, throwing up the black spores into vivid relief; but even with reflected light, such as Micheli probably employed, the black spores stand out very clearly on the lighter background of the general hymenial surface.

In searching fungi for bodies equivalent to seeds, Micheli had been highly successful; but this did not satisfy him. He was also anxious to discover floral organs comparable with those of the Phanerogamia. Accordingly, on observing at the free margins of the gills of species of stiped Agaricineae (his Fungus) some peculiar threadlike-cells (Pl. I, F, I, N, K), he immediately interpreted these structures as being apetalous flowers. He says: "At the margin of the laminae are produced apetalous flowers, naked, consisting of nothing but a cylindrical filament; in some species solitary or distinct from one another; in others, however, collected into a mass or tuft."[3] The margins of the gills of many of the Agaricineae, e.g. *Hypholoma Candolleanum*, *Psilocybe foenisecii*, *Lepiota cepaestipes*, the cultivated Mushroom, etc., are known to consist of projecting hyphae of a more or less specialized kind. Doubtless in some cases, it was these sterile elements which we may term *marginal hairs*, that Micheli took for flowers; while in other cases, as some of his illustrations seem to show, it may have been the groups of four spores belonging to projecting basidia. The flowers

[1] Micheli, Nova Plantarum Genera, p. 133; *cf.* Tab. 73, fig. 1, I, Tab. 75, fig. 9, and Tab. 79, fig. 4.

[2] A. H. R. Buller, The Production and Liberation of Spores in the genus Coprinus, Trans. Brit. Mycological Soc., 1911, pp. 348-350.

[3] Micheli, *loc. cit.* p. 133. Illustrations of the supposed flowers are shown in Tab. 73 and Tab. 76.

were supposed to be restricted to the gill edge, and therefore to arise apart from the seeds which had been found scattered over the surface of the gill sides. Boletus (his Suillus) was also regarded by Micheli as containing his peculiar flowers, for, in referring to the underside of the pileus, he says: "In the mouths of the tubes and in the upper part of the stipe while the pileus is expanding, are found flowers which are apetalous, monostemonous (i.e., consisting of a single filament), sterile and naked, or in other words destitute of calyx, pistil, and stamens" (Pl.II, A, G, H).[1] To succeeding botanists, what it was that Micheli saw in the Boleti has never been clear, for anything like that which he represented at the mouth of the hymenial tubes does not exist. Possibly in his sections, he saw some of the elongated spores projecting on their sterigmata, but failed to recognise them when seen in side view as the same things which he knew from face view observations of the hymenium, and so interpreted them as flowers. In making his sketch (Pl. II, G), he evidently drew his hymenial tube about twice the natural size and then added the "flowers" at the mouth, but he seems to have given these supposed flowers the same magnification that they had when seen under the microscope. Possibly it was by intentionally combining macroscopic and microscopic features that Micheli hoped to make clear to others the relationship of the supposed flowers to the seed-bearing tubes.

In a third genus, his Agaricum, which included dimidiate Hymenomycetes of various kinds, Micheli also described flowers (Pl. I, N, O), and in exactly the same words as for Boletus.[2] Micheli therefore regarded the Hymenomycetes as simple forms of seed-plants. It is to be noted that he did not call his flowers stamens: in his genus Fungus, he simply says that they consist of nothing but a filament; whilst in Agaricum and Suillus, he says that calyx, pistil, and stamens are absent. Some subsequent writers have erroneously spoken of Micheli's *stamens* when they should have said his *flowers*.

The function of the hairs seen by Micheli at the margins of the gills, although under investigation, is still unknown. According to Knoll, in some cases at least, these hyphae are hydathodes.[3] It seems to me possible that in some species they may be useless structures which could well be done without. However, this may be, it has long been known that they cannot possibly be flowers. In giving this interpretation, Micheli made one of those errors from which the pioneer, entering a new and a strange world, can hardly escape.

[1] *Ibid.* p. 126; also Tab. 68.

[2] *Ibid.* p. 117.

[3] F. Knoll, Untersuchungen über den Bau und die Funktion der Cystiden und verwandter Organe, Jahrb. f. Wiss. Bot., Bd. 50, pp. 453-501.

Micheli's view that the flowers of a lamellate fungus are situated on the margins of the gills, remote from the seeds which are scattered over the gill-sides, now seems very curious; but it must be remembered that, at the beginning of the eighteenth century, the functions of the different parts of true flowers were not generally understood. Camerarius (1691 and 1694) had proved by experiment that anthers are necessary for the production of embryos, but the theories of fertilization put forward by Morland (1703,) Geoffroy (1711), and Vaillant (1718), show us that no one at that time understood how pollen led to the fertilization of the ovules. It was not until 1846 that Amici and Robert Brown demonstrated that pollen-tubes which grow down the style, enter the micropyles of the ovules, and cause the egg-cells to develop into embryos.[1] There is nothing to show that Micheli in 1729 believed that fertilization is necessary for the development of the so-called seeds of fungi. It is not improbable that he thought that they could attain maturity without its help.

In studying the gills of certain Agarics which grow on manure heaps, Micheli discovered those peculiar organs of the hymenium which we now call *cystidia* (Pl. I, P Q, R). He says: "In some other species of Fungi and especially in those which arise on the dung of horses, cows, and similar animals, I have observed something that is noteworthy, to wit, that the surface of their lamellae is ornamented, not merely with seeds but also with transparent bodies which in some species are conical, K, and in others pyramidal, L."[2] The letters K and L refer to his Plate 73. Turning from the structure to the function of these bodies, he continues: "They are made by the wise device of nature so that one lamella does not touch another, to the end that the seeds produced between them should not be hindered in their development or that they should not fall except when they ought to fall." Micheli's Figure I in his Plate 73 (Pl. I, P) gives a fairly correct idea of the distribution of the cystidia over the gill surfaces of such Coprini as *Coprinus fimetarius* and *C. macrorhizus*. The conical bodies were doubtless cystidia seen in the turgid condition, whilst the pyramidal ones were cystidia which had collapsed on drying and which therefore had developed angles. The gills in all probability were examined in air, the more modern method of mounting preparations in water under a coverglass being then unknown. The cystidia of the Coprini do not fall with the spores as Micheli supposed, but their disappearance is due to autodigestion as I was able to prove in 1910.[3]

[1] For a history of the early study of the flower, *cf.* L. C. Miall, The Early Naturalists, their Lives and Works, London, 1912, pp. 337-345.

[2] Micheli, *loc. cit.* p. 133.

[3] A. H. R. Buller, The Function and Fate of the Cystidia of *Coprinus atramentarius* Ann. of Bot., Vol. XXIV, 1910, pp. 613-630.

Micheli regarded cystidia as mechanical props or stays which keep adjacent gills apart in the interests of spore-development and spore-discharge. In the case of the Coprini, this view has been strengthened by the anatomical work of Wettstein, [1] and its correctness for *Coprinus atramentarius* has been made sufficiently certain by my own researches.[2] To demonstrate the excellence of Micheli's suggestion has taken nearly two centuries.

As we have now seen, Micheli discovered three kinds of structure upon the gills of Agarics: spores in groups of four, hairs on the gill margins, and cystidia on the sides of the gills; but he failed to observe basidia, sterigmata, and paraphyses, furthermore, his investigations did not extend to the trama. These other gill elements could be brought to light only after the microscope had been considerably improved.

Micheli was not contented with merely supposing that the little grains which he had found with the microscope were the seeds of fungi, but he performed a series of highly original and carefully thought-out experiments which he called "Observations," to demonstrate that the supposed reproductive bodies are able, as a matter of fact, to give rise to plants of the same species as those which bear them. He made his tests of the seed hypothesis with Agarics, and with three of the commonest Moulds: Mucor, Botrytis, and Aspergillus, (Pl. IV). He planted the spores on a suitable culture medium—dead leaves for Agarics, freshly cut and therefore practically sterile pieces of melon, quince, and pear for the Moulds—and watched the result. The experiments with the Moulds came off with great certainty and success. A few days after sowing the spores, a mycelium was produced which in Mucor gave rise to sporangia containing spores, and in Botrytis and Aspergillus developed the characteristic conidiophores bearing spores. The new crops of spores were again sown with results similar to those obtained in the first instance. The experiments were not only repeated but varied in such a way as to afford convincing proof that the so-called seeds really are reproductive bodies. The actual germination of the spores, however, was not observed. The experiments with the Agarics were naturally more difficult to carry out. Fruit-bodies of particular species were allowed to shed their spores on certain kinds of dead leaves which had been carefully chosen. The infected leaves were then placed in the open in heaps, in shady places, where the fungi used for the experiments had never been seen. Some months afterwards the heaps of leaves were carefully examined. In a number of them apparently

[1] R. Wettstein, Zur Morphologie und Biologie der Cystiden, Sitz.-ber. Kais. Acad. Wiss. mat.-naturw. Kl., Wien, Bd. XCV. Abt. 1, 1887, pp. 10-20.

[2] A. H. R. Buller, *loc. cit.*

nothing had happened; but, in a few, a mycelium was observed in course of development. The mycelium was watched, and after a time was found to have produced fruit-bodies of the same species as those from which the spores had been taken to start the experiments. After having discussed his negative as well as his positive results, Micheli concluded: "It is sufficient for me for the present that I have sown the seeds and have seen the fungi arise from them." On account of the uncertaitny of these experiments, he advises those who want to raise fungi for profit to confine themselves to the Mushroom which he says is grown "in oblong heaps of dung which by gardeners are called by the common French name of *Couches*."

At the present day, there is no more familiar operation in the botanical laboratory than the raising of Moulds and other fungi on various culture media. Micheli's experiments are therefore historically of high interest. In order to show exactly how they were carried out a translation of the seven "Observations" will now be given.[1]

Observation I.

On the tenth of June, 1718, I collected in the country around the town, many species of fungi which I had never seen coming up in the woods of the royal pleasure gardens commonly called Boboli. This was done to obtain the seeds of different species. Then I spread on the table in my room many leaves of Ilex, Quercus, Laurus, Fraxinus, and the like, which had already fallen some time but were not spoiled or rotten, keeping each kind separate. On the different heaps of leaves, I placed either erect or lying down, several of the fungi; on some, one species, but on others, several species, simply for the purpose of allowing each fungus to deposit its seeds on the leaves. When three or four hours had passed, the leaves were turned, not merely in order that each leaf should receive seeds, but also that the seeds should not be collected in a heap in one place. When that was done and as much of the seeds as there was need of had been collected, I threw away the fungi and divided the different kinds of leaves into two parts, of which I carried the one into a thicket of the Boboli gardens and the other outside the town to a forest of Mount Olivet. I laid all these leaves in a place suitable for producing fungi, i.e., shady, among semi-rotten leaves of kinds different from those which had been covered with the seeds of the fungi, and I so placed the different heaps that they could not be mixed either with one another or with the leaves lying around.

[1] The original Latin accounts of these experiments are in the *Nova Plantarum Genera*, pp. 136-139. I am indebted to Miss Gladys Workman and Mr. W. B. Grove, M.A., for valuable assistance in making the translations.

From the twentieth of August to the fourth of Setpember, there were several wet days, so, on the twentieth of September, I went to Mount Olivet and on the following day to the Boboli gardens to see whether I could find anything in particular on the heaps of leaves. In the Boboli gardens on some of the heaps which had been noted, and especially on those consisting of the leaves of the Ilex and Laurus, I saw that many of the seeds had increased to the size of a grain of Millet, and their margin went off into very white and thin down, and all were producing capillary and somewhat hairy roots, whence I conjectured that the fungus had already begun to grow. That the fact was really so, I found out after a few days when, in some of the heaps, I saw pilei beginning to break out from the down, and in others the whole form of the fungus plainly showing itself.[1] On the eighth of October, I visited the same places, not only for the sake of noting the progress of the fungi which had come into existence, but also of understanding, if it were possible, for what reason none had yet been observed growing on the other heaps. Not being able to see the reason easily, I therefore returned frequently to watch the progress of those which had arisen, observing them only with the eyes and not touching them at all by hand. And so toward the end of October, and after several days alternately fine and wet, they had at length become bigger, and projecting above the leaves were several of the fungi which had been produced from the seeds scattered through the heaps. I repeated these observations several times at the beginning of summer and also in autumn; but since the growth of the seeds generally depends on the chance weather of nature, i.e., on the alternation of fine and wet days which does not always happen opportunely, I have observed almost innumerable cases where it befell that the fungi did not grow, or their formation was hastened or delayed, or they were brought forth in greater or less abundance. Hence it follows that on sowing the seeds, it is very difficult to determine anything with certainty, especially since I have not yet examined everything in detail; but in the meanwhile, it is sufficient for me that I have sown the seeds and have seen fungi arise from them. If anyone, however, desires a sure method of cultivating fungi in order to get profit from them, I am of the opinion that he should employ only that method which gardeners use, namely, oblong heaps of dung which by them are called by the French name of *Couches*. From these they raise meadow fungi, and indeed from the seed and not from the heating dung as they think. This seed is naturally mixed with the dung itself or with the earth or things of that kind which serve for the composition of the oblong heaps. The manner of preparing these heaps is shown by Quintinaeus in his book,

[1] *Cf.* Pl. 1, Figs. D and E.

lib. VI, pp. 292, 327, and 333, but far more exactly by Tournefort in Comm. Ac. R. Sc., An. 1707, pag. 72.

Observation II.

On the fifth of November of the same year (1718) I took a piece of Melon (Pepo oblongus, C.B.Pin., 311) about four inches long and two inches wide and thick. Next, with a very soft brush, I collected from some other place the seeds from the dark sparkling heads of Mucor.[1] I then smeared them on to the surface of the piece of melon on one side only, and put it in a place in no wise exposed to wind or sun. On the tenth of the same month, the infected part appeared everywhere white and strewn with a very thin down, like white cotton, which on the twelfth attained almost an inch in height and assumed a greyish colour; and some of the filaments of the down began to appear with white heads. On the fourteenth, the other filaments bore heads of the same kind. Finally, on the fifteenth, all the heads had become black, and after that the seeds came to maturity.

Observation III.

With the seeds which had been produced in the heads of the Mucor in the previous experiment, on the sixteenth day, I smeared another portion of the same melon on one side, and on the other side I placed the seeds of the capitate Aspergillus with glaucous heads and rounded seeds.[2] On both sides, within the same interval of time as I have mentioned above, they sprang up, grew in the same manner as before, and produced seed after their kind. When I had done this several times, always using those seeds which each new crop of plants produced in its turn, I still observed no difference in the plants which sprang up.

Observation IV.

On the sixth day of December, I took another piece of the melon of the same size and shape as before. In it I made five hollows, distinct from one another, and in them I placed a small piece of a fig infected with Mucor whose black and shining heads were already ripe. On the eighth day, many of the Mucor plants had bowed their heads;

[1] Probably *Mucor Mucedo* Linn. *Vide* Plate IV, Figs. A and B. (Micheli, Tab. 95, Fig. 1.)

[2] Probably *Aspergillus glaucus* Link. *Vide* Plate IV, Fig. D. (Micheli, Tab. 91, Fig. 1.)

others were lowered around the holes where they had deposited seeds. Then, on the twelfth day, the whole surface of the piece of melon appeared covered over by the Mucor which, on the eighteenth day of the same month, brought its seeds to maturity. On the nineteenth day of the month, on certain parts of the surface of the above mentioned piece of melon, there appeared a white down, but in other places down of an ashen hue, arising from seeds which had fallen by chance from elsewhere on the melon. On the twentieth day, these grew up and one turned into Botrytis,[1] branched, grey-coloured, with round seeds; the other into the capitate Aspergillus[2] with glaucous heads and round seeds; but the black ones produced from seeds placed there by us forthwith perished.

Observation V.

On the fourth day of November, I infected the sides of two pieces of the same melon with the seeds of the Botrytis[3] which was branched and grey with round seeds. One of these pieces, I placed in a forcing house; the other in a small room with the window open. On these two pieces, on the seventh day, and on the same two sides which had been covered by seeds, granules appeared everywhere, like those which one may observe on the skin of what we commonly call shagreen (*sagri*), or rather a piece of pear which has been cut open for some days, but more sparsely than these. On the eighth day, these grains developed into very minute and almost imperceptible down, and especially those which were observed on the piece of melon which had been placed in the forcing house. On the evening of the ninth day, on both sides of the pieces, this down had much increased, so much so that they appeared as if covered with frost, or as it were by nitre which comes out on walls. The upper part of each piece of melon which had not been inoculated with the Botrytis seed was still intact. On the thirteenth day, the down on both pieces, at the infected spots, had produced heads which changed to a glaucous colour not differing from that of the heads from which I took the seeds, while not even a tiny plant of a second species of Botrytis or of Mucor had appeared. Howbeit, on the upper part of the piece of melon not placed in the forcing house, certain masses of white down had arisen, which on the eighteenth day

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[1] Probably *Botrytis umbellata*, Fr. *Vide* Plate IV, Fig. G. (Micheli, Tab. 91, Fig. 2.)

[2] Probably *Aspergillus glaucus* Link. *Vide* Plate IV, Fig. D. (Micheli, Tab. 91, Fig. 1.)

[3] Probably *Botrytis umbellata*, Fr. *Vide* Plate IV, Fig. G. (Micheli, Tab. 91, Fig. 2.)

developed into true plants, on the twentieth day came to maturity, and then Mucor was revealed with black and shining heads, no one having planted it, but the seeds having fallen there by chance.

Observation VI.

On the first day of November, I infected another piece of the melon with the seed of the capitate Aspergillus which has spherical and glaucous heads.[1] On the fourth dav I observed no change. On the evening of the eighth day, the surface of the melon had a granular appearance similar to that already mentioned for the pear and the skin of shagreen (*sagri*), so that, on account of the abundance of the flakes of the investing down, it seemed like frost. On the thirteenth day, the down had grown and come to its final perfection, for it put forth heads and turned into plants of its own kind: and on the eighteenth day it disappeared. Howbeit, on a portion of the infected melon of very small extent which had not been inoculated with the seed of Aspergillus, another kind of plant was produced which showed itself clearly on the twenty-fourth day and came to maturity. It was indeed the branched, grey Botrytis with round seeds.[2] On the twenty-seventh day, in certain places where the (capitate) Aspergillus already on the eighteenth day had come to perfect maturity, there appeared the very slender, white Aspergillus which is branched like Gramen Dactyloides, and has round seeds.[3] Both these plants had sprung from seeds which had fallen on the piece of melon by chance.

Observation VII.

On the thirtieth day of December, I took a piece of the melon and shaped it into a triangular pyramid.[4] Then, choosing a piece of a quince and also of an almost ripe pear, commonly called *Spina*, I formed them into truncated pyramids, with their apices removed, giving the piece of quince a pentagonal, and the piece of pear a hexagonal base.[5] On the individual faces of the pyramids, I sowed the seeds of Mucor, Aspergillus, and Botrytis, keeping each kind separate,

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[1] Probably *Aspergillus glaucus* Link. *Vide* Plate IV, Fig. D. (Micheli, Tab. 91, Fig. 1.)

[2] Probably *Botrytis umbellata* Fr. Illustrations *loc. cit.*

[3] Probably *Penicillium digitatum* Sacc. *Vide* Plate IV, Fig. E. (Micheli Tab. 91, Fig. 3.).

[4] *Vide* Pl. IV, Fig. J.

[5] *Vide* Pl. IV, Figs. K and L.

so that on the piece of melon I had placed three kinds, on the quince on five sides five kinds, and lastly on the pear on six sides six kinds, just as is shown in the Plate of Mucor at the letters A, B, and C.[1] All these species of seeds began to germinate from the fourth to the fifth or sixth day of the month, as I observed. They developed into plants according to their seed, of which some attained to their maturity on the tenth day, others on the twelfth, others on the thirteenth, and finally others on the fifteenth: and they produced the seeds of their kind. I kept these seeds separate, and again and again planted the seeds produced in like fashion from them; and then I always observed the same mode of growth in them, not in one trial only but however often and whenever I attempted it, without any difference whatsoever other than in the rate of growth or in the earlier or later ripening. These discrepancies could arise from various causes, perhaps from the difference in the time of the year, the place, or the structure of the substrata, or because the seeds were too ripe or immature.

At the present time, in tracing out the life-history of a fungus, we sow single spores in a sterilised nutrient medium and thus obtain pure cultures. The progress of development is then watched step by step with the microscope, so far as is necessary, until a new crop of spores is produced. In particular it was by the successful employment of this method that Brefeld and other modern investigators have taught us so much. Micheli, on the contrary, made what we may call *mass experiments*. He did not sterilize his nutrient medium, but by cutting a piece out of a fresh melon or quince or pear he obtained a substratum which was practically sterile. By sowing the spores of his Moulds in thousands, he obtained a crop of new plants which simply swamped any other weed-fungi which might have become planted by accident.

The possibility of the fall of invisible spores upon a culture medium from the air, which may germinate and produce plants, was fully realized by Micheli as his remarks in his Observations IV, V, and VI show. The way was thus prepared for the final overthrow of the theory of spontaneous generation by Pasteur one hundred and fifty years later.

The establishment of the true origin of fungi by means of the highly original and ingenious experiments recorded in his *Nova Plantarum Genera* will always entitle Micheli to a place in the front rank of the founders of mycology.

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[1] In my Pl. IV, at J, K, and L.

Explanation of Plates I, II, III and IV.

Illustrating Professor Buller's Address on Micheli and the Discovery of Reproduction in Fungi.

All the figures in the following plates are taken from Micheli's *Nova Plantarum Genera* (1729) and have been copied and arranged by A. H. R. Buller.

Plate I.

Drawings illustrating reproduction in laminated Hymenomycetes. A, isolated spores; B, seventeen developmental stages; C, a full-grown fruit-body with the pileus cut in two showing the spores (*seeds* of Micheli) on the gills; D and E, two leaves showing three stages, *a*, *b*, and *c*, in the development of a fungus. F. I, P, N, and K, isolated gills of various fruit-bodies all bearing spores: in F, P, N, and K, the spores are scattered, but in I they are in groups of four. In F, K, and N, there is a fringe of isolated "flowers" on the free gill margin, whilst in I the "flowers" are in small tufts. The "flowers" of F are shown magnified at G, those of K at L and M, those of I at J, and those of N to the left of O. The gill P is bearing cystidia (*transparent bodies* of Micheli) and spores; Q, two conical cystidia; R, two pyramidal cystidia. H, spores from the gill F; on the right of O, spores from N. A-C, F-J, P-R, from Micheli's Tab. 73; D, E, from Tab. 77; L-M, from Tab. 76: N-O from Tab. 65.

Plate II.

Drawings illustrating reproductive organs and spores in Boletus and Hydnum. A-H, Suillus (=*Boletus edulis* Fr.) A, the pileus of a fruit-body cut in two to show the structure: the layer of tubes at *b* is shown as easily separating from the flesh at *a*. B, a single tube. C, several tubes adhering together. D, a tube cut open to show the spores (*seeds* of Micheli). E, isolated spores from a tube. F, showing spores at the mouth of a tube, as seen with the microscope. G, an inverted tube showing six "flowers" at its mouth. H, isolated "flowers" consisting of a single filament, as seen with the microscope. I-K, Erinaceus (=*Hydnum repandum* Fr.). A fruit-body inverted to show the teeth. J, two teeth. K, spores from the teeth. A-H from Micheli's Tab. 68; I-K, from Tab. 72.

Plate III.

Figures illustrating various fungi with their spores. A, Mucilago (a plasmodium on a leaf). B-E, Clathroides (=*Arcyria punicea* Pers.); B, fruit-bodies natural size; C and D, the same enlarged,

with C exhibiting the expanded capillitium network; E, some of the spores (*seeds* of Micheli). F and G, Clavaria (=*Clavaria fragilis* Fr.); F, fruit-bodies; G, spores. H, Lycoperdon (=*Lycoperdon plumbea* Fr.) with spores coming out through the stoma of the endoperidium; six capillitium fibres shown above. I-K, Carpobolus (=*Sphaerobolus stellatus* Tode); I, fruit-bodies natural size on a piece of wood, the dotted lines indicating the direction of flight of several peridiola; J, part of a drawing showing two fruit-bodies on a stick enlarged, on the left a section exhibiting the two layers of the stellate peridium containing a peridiolum before discharge, on the right a fruit-body in which the inner layer of the peridium has suddenly become inverted and has shot forth the peridiolum as indicated by the dotted line; K, spores from the interior of a peridiolum. L, Fungoides (=*Peziza* sp.) with the spores puffing out into the air. M, N, Lichen-Agaricus (=*Sphaeria* sp.?); M, five perithecia much enlarged; N, three rows of eight spores each, each row having doubtless been seen in an ascus. O, P, Lichenoides (=*Pertusaria communis*?), enlarged drawings from a lichen; O, some perithecia showing the stomata and asci; P, two isolated asci. A, from Micheli's Tab. 96; B-E, from Tab. 94; F, G, from Tab. 87; H, from Tab. 97; I-K, from Tab. 101; L, from Tab. 86; M, N, from Tab. 55; O, P, from Tab. 56.

PLATE IV.

Figures illustrating the Moulds and material which Micheli employed in his classical experiments on reproduction. Macroscopic and microscopic appearance: A and B, of *Mucor vulgaris, capitulo lucido, per maturitatem nigro, pediculo griseo* (=*Mucor Mucedo* Linn.); D, of *Aspergillus capitatus, capitulo glauco, seminibus rotundis* (=*Aspergillus glaucus* Link); E, *Aspergillus albus, tenuissimus, graminis dactyloides facie, seminibus rotundis* (=*Pencillium digitatum* Sacc.); and F, G, *Botrytis ramosa, cinerea, seminibus rotundis* (=*Botrytis umbellata* Fr.). In B: *a*, an unopened *capitulum* (=sporangium); *b* and *c* show the internal cavities, and *d* the *semina* (=spores) emerging. C, the *placenta* (=columella) of a capitulum. H, a chain of *semina* (=spores) from an Aspergillus. I, the *semina* separated. J, a piece of melon in the shape of a triangular pyramid on the faces of which three different kinds of Moulds (B, D, and G, Mucor, Aspergillus, and Botrytis) were sown and have sprung up. K, a piece of quince in the form of a truncated pentagonal pyramid, with five crops of Moulds. L, a piece of a pear in the form of a truncated hexagonal pyramid with six crops of spores. A-C, J, K, L, from Micheli's Tab. 95; D-I from Tab. 91.

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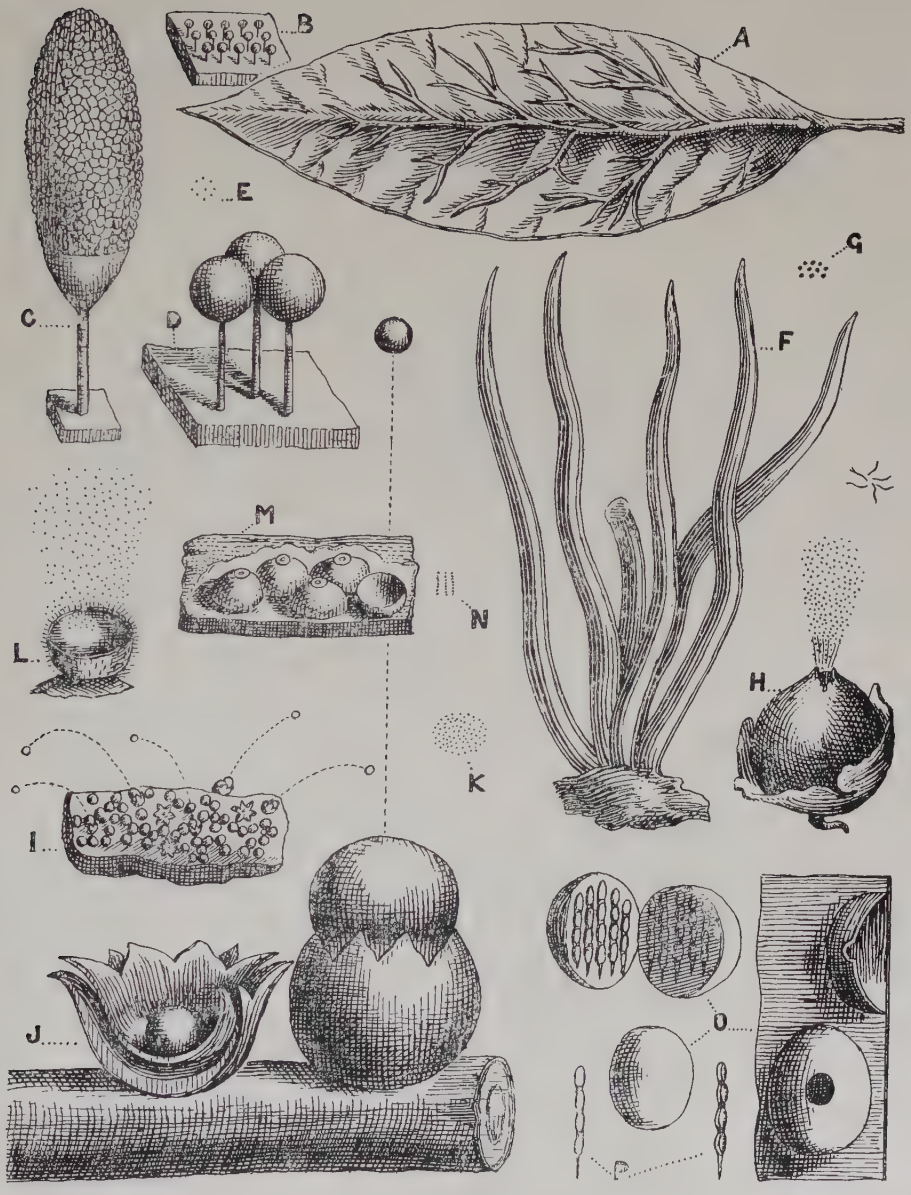
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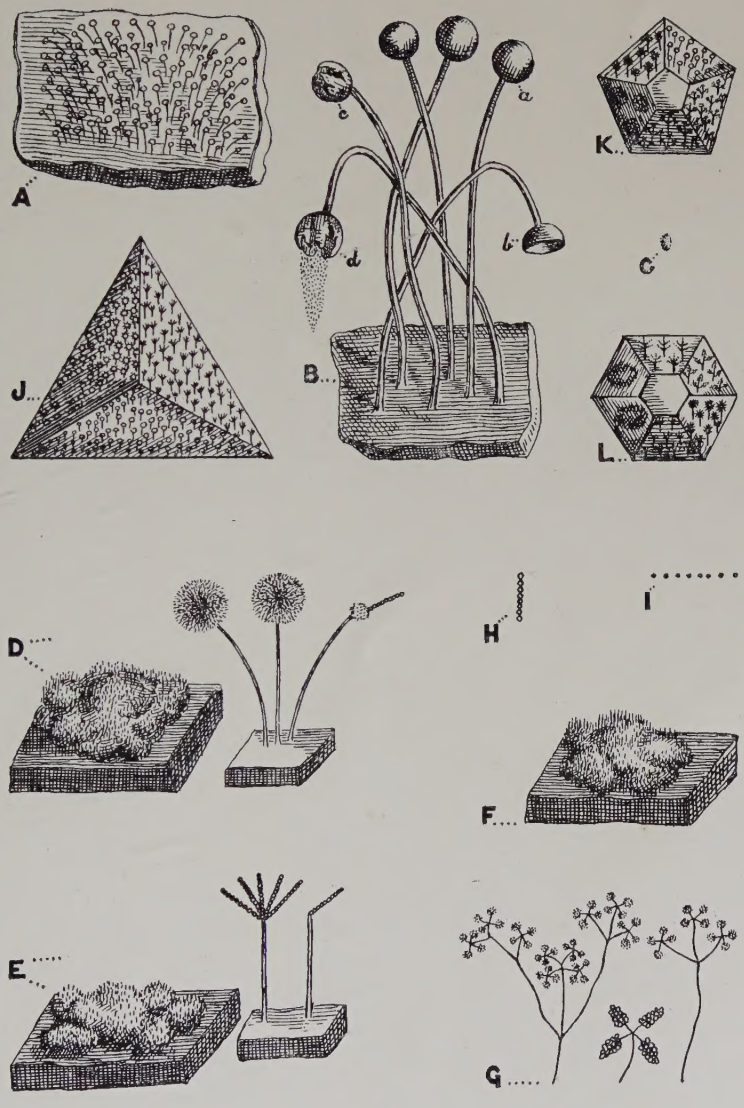
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